Examples- AMPLITUDE MODULATION (AM)

Communications Principles (EE 322)

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Example 1

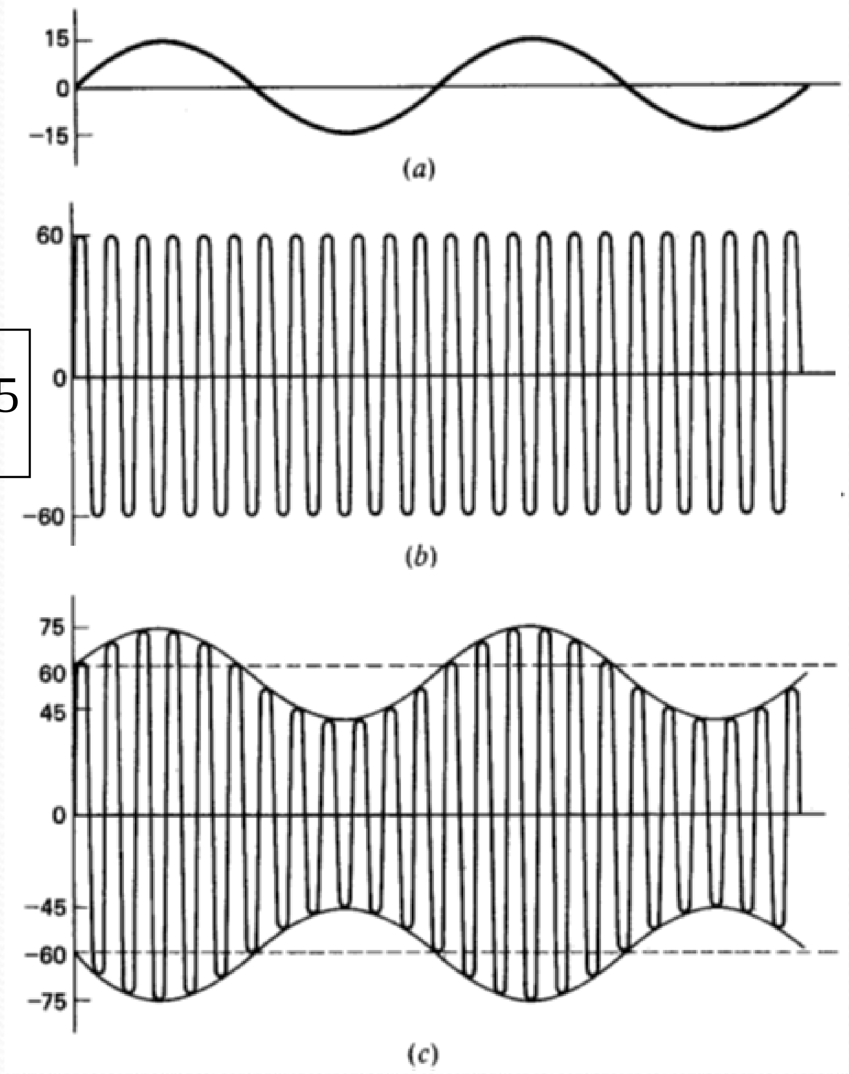
An audio signal 15 sin(2π 1500 t) amplitude modulate a carrier=60 sin(2π 100,000 t)

a) Sketch the audio signal
b) Sketch the carrier
c) Construct the modulated signal
d) Determine the modulation index Percent modulation
e) What are the frequencies of the audio signal and the carrier
f) What frequencies would show up in a spectrum analysis of the modulated wave?

Example 1 Solution

a) audio signal
b) the carrier
c) the modulated signal
d) Modu. index $m = \frac{A_m}{A_c} = 15/60 = 0.25$

e) percentage of modulation
=m*100%=25%
f) f_m=1500Hz
f_c=100,000Hz
a) f_c, f_c+f_m, f_c-f_m
=100kHz, 101.5KHz, 98.5KHz



Example 2

- For a conventional AM modulator with a carrier freq of f_c = 100 kHz and the maximum modulating signal frequency of f_{mmax} = 5 kHz, determine:

a) Freq limits for the upper and lower sidebands.

b) Bandwidth.

c) Upper and lower side frequencies produced when the modulating signal is a single-freq 3-kHz tone.

d) Draw the output freq spectrum.

Example 2 Solution

- Given f_c = 100 kHz and $f_{m(max}$ = 5 kHz:

Freq limits for the upper and lower sidebands.

$F_{upper}= f_c+ f_{m(max)}=$ 100 kHz + 5 kHz= 105 kHz

$F_{lower}= f_c- f_{m(max)}=$ 100 kHz - 5 kHz= 95 kHz

Bandwidth.

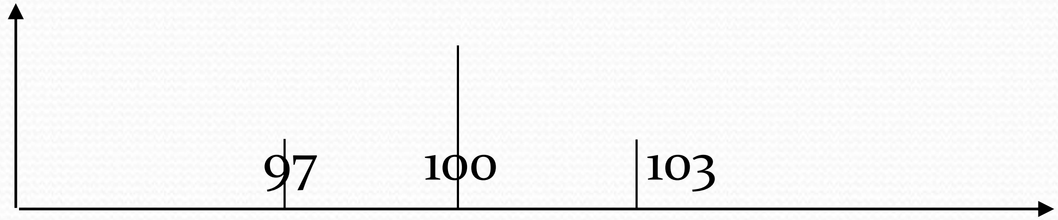
$B=2*f_{m(max)}=10$ kHz

Upper and lower side frequencies produced when the modulating signal is a single-freq 3-kHz tone.

$F_{upper}= f_c+ f_m=$ 100 kHz + 3 kHz= 103 kHz

$F_{lower}= f_c- f_m=$ 100 kHz 1 - 3 kHz= 97 kHz

Draw the output freq spectrum.



Example 3

- Suppose that V_{max} value read on an oscilloscope screen is 4.6 divisions and V_{min} is 0.7 divisions. Calculate the modulation index (modulation sensitivity) and percentage of modulation.
- Solution $\boxed{m = \frac{A_m}{A_c} =}$

$$A_m = \frac{1}{2}(A_{\max} - A_{\min})$$

$$A_c = \frac{1}{2}(A_{\max} + A_{\min})$$

$$\Rightarrow \quad m = \frac{\frac{1}{2}(A_{\max} - A_{\min})}{\frac{1}{2}(A_{\max} + A_{\min})} = \frac{(A_{\max} - A_{\min})}{(A_{\max} + A_{\min})}$$

$$m = \frac{(4.6 - 0.7)}{(4.6 + 0.7)} = 0.735$$

- percentage of modulation =m*100%=73.5%

Example 4

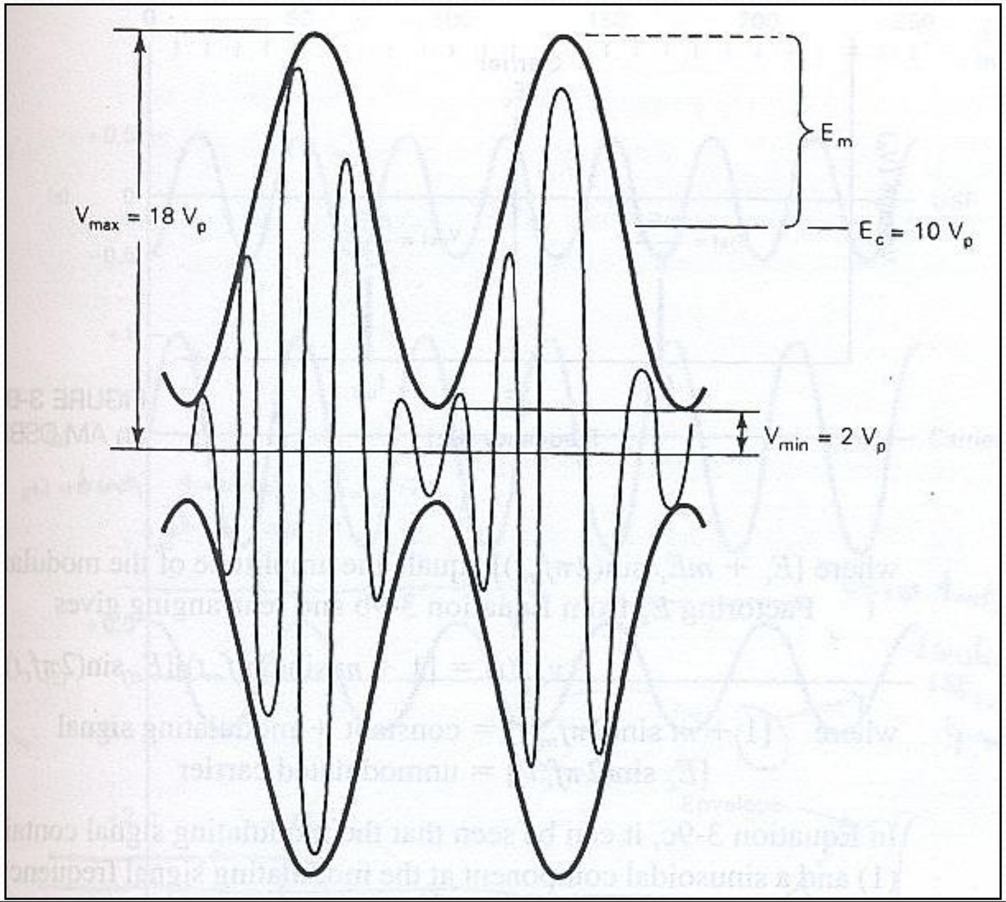
- How many AM broadcast station can be a accommodated in a 100-khz bandwidth if the highest frequency modulated carrier is 5 kHz.

Solution

- number of stations= total bandwidth/ 2*BW
  - $=(100*10^3)/(10*10^3)=10$ stations

Example 5

- For the AM waveform shown in Figure below, determine
  a) Peak amplitude of the upper and lower side frequencies.
  b) Peak amplitude of the unmodulated carrier.
  c) Peak change in the amplitude of the envelope.
  d) Modulation index.
  e) Percent modulation.



$$+V_{max} = E_c + E_{usb} + E_{lsb}$$

$$+V_{min} = E_c - E_{usb} - E_{lsb}$$

$$-V_{max} = -E_c - E_{usb} - E_{lsb}$$

$$-V_{min} = -E_c + E_{usb} + E_{lsb}$$

Example 6

- For an AM DSCFC wave with a peak unmodulated carrier voltage $V_c = 10\ V_p$, a load resistor of $R_L = 10\ \Omega$ and $m = 1$, determine

a) Powers of the carrier and the upper and lower sidebands.

b) Total sideband power.

c) Total power of the modulated wave.

d) Draw the power spectrum.

Example 6 Solution

$$\boxed{P_c = \frac{(V_c/\sqrt{2})^2}{R} = \frac{V_c^{\ 2}}{2R}}$$

$$P_{usb} = P_{lsb} = \frac{(mV_c/2)^2}{2R} = \frac{m^2V_c^{\ 2}}{8R}$$

- Powers of the carrier and the upper and lower sidebands.

$$P_{usb} = P_{lsb} = \frac{m^2}{4}\left(\frac{V_c^{\ 2}}{2R}\right) = \frac{m^2}{4}P_c$$

- Total sideband power.

$$P_{sb}=p_{us}+p_{lo}$$

- Total power of the modulated wave.

$$P_{total}=p_c+p_{us}+p_{lo}$$

- Draw the power spectrum.

Example 7

Determine the power content of the currier and each of the sidebands for an AM signal having a percentage modulation of 80% and a total power of 2500 W.

Solution

$$P_t = P_c + \frac{m^2}{4}P_c + \frac{m^2}{4}P_c$$

$$2500 = P_c + \frac{(0.8)^2}{2}(P_c) = 1.32P_c$$

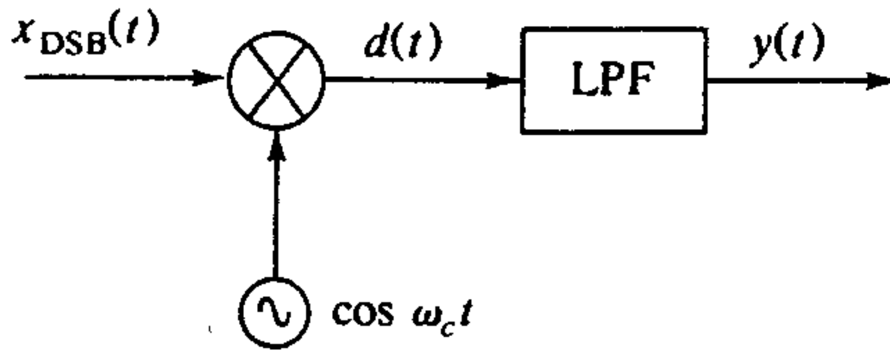
$$P_c = 1898.3W$$

$P_{usb}+p_{lsb}$=2500-1898.3=606.1W

$P_{usb}=p_{lsb}$=303.05W

Example 8

Verify that the message signal m(t) is recovered from DSB signal by first multiplying it by a local sinusoidal and



then passing the resultant signal through a lower-pass filter in a time domain and in the frequency domain.

Solution

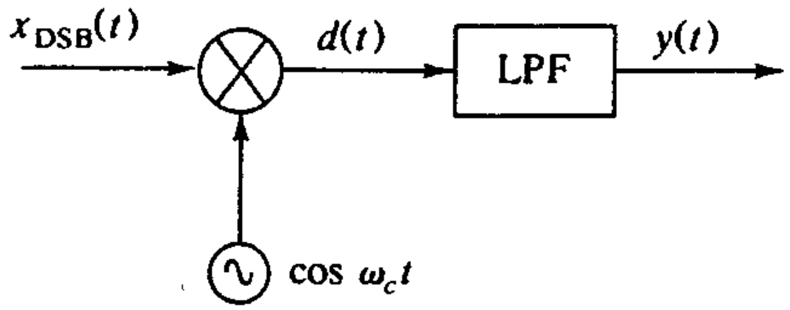
$$d(t) = x_{\mathrm{DSB}}(t) \cos \omega_c t = [m(t) \cos \omega_c t] \cos \omega_c t$$

$$= m(t) \cos^2 \omega_c t$$

$$= \tfrac{1}{2} m(t) + \tfrac{1}{2} m(t) \cos 2\omega_c t$$

$$y(t) = \tfrac{1}{2} m(t)$$

Example 9



- Evaluate the effect of
- a phase error in the local oscillator on synchronous DSB demodulation as shown.

Solution

Let the phase error be ϕ, then the local carrier is expressed as $cos\omega_c t + \emptyset)$. Now

$$x_{DSB}(t) = m(t)\cos \omega_c t$$

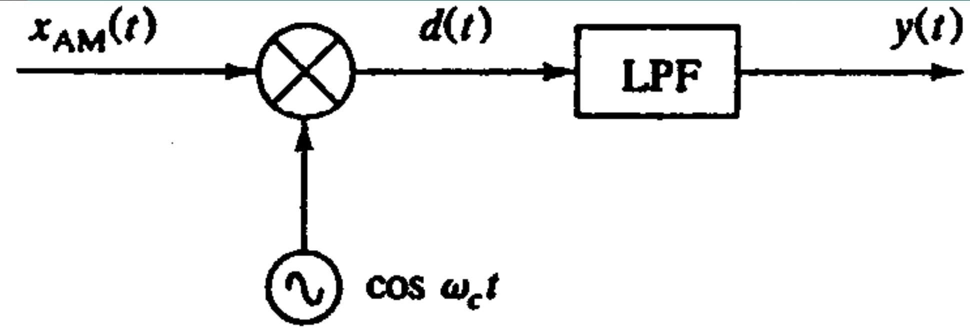
$$\begin{aligned} d(t) &= [m(t)\cos \omega_c t]\cos(\omega_c t + \phi) \\ &= \tfrac{1}{2}m(t)[\cos \phi + \cos(2\omega_c t + \phi)] \\ &= \tfrac{1}{2}m(t)\cos \phi + \tfrac{1}{2}m(t)\cos(2\omega_c t + \phi) \end{aligned}$$

then

$$y(t) = \tfrac{1}{2}m(t)\cos \phi$$

The output is completely lost when $\emptyset = \pm\frac{\pi}{2}$

Example 10



- Show that a synchronous demodulator can demodulate an AM signal $x_{am(t)} = [A + m(t)] \cos \omega_c t$

Solution

From the fig

$$d(t) = x_{\mathrm{AM}}(t) \cos \omega_c t = [A + m(t)] \cos^2 \omega_c t$$

$$= \tfrac{1}{2}[A + m(t)] + \tfrac{1}{2}[A + m(t)] \cos 2\omega_c t$$

Hence after the low pass filter

$$y(t) = \tfrac{1}{2}[A + m(t)] = \tfrac{1}{2} m(t) + \tfrac{1}{2} A$$

A blocking capacitor will suppress the direct-current term (A/2).

Example 11

- A SSB signal contains 1KW. How much power is contained in the sidebands and how much at the carrier frequency?

Solution

In a SSB transmission, the carrier and one of the sidebands eliminated. Therefore, all the transmitted power is transmitted at one of the sidebands regardless of the percent modulation. Thus

$$P_{ssb}=1Kw$$

$$P_c=0W$$

Example 12

For an AM DSBFC wave with a peak unmodulated carrier voltage V_c = 10 V_p, frequency of 100kHz, a load resistor of R_L = 10 Ω, frequency of modulating signal of 10kHz and m = 1,

a) determine the following

i) Powers of the carrier and the upper and lower sidebands.

ii) Total power of the modulated wave.

iii) Bandwidth of the transmitted wave.

iv) Draw the power and frequency spectrum.

b) For the same given values, determine questions (ii)-(iv) for a AM DSB-SC, AM SSB-FC and AM SSB-SC systems. Determine also the percentage of power saved in each of the system design.

Example 12..cont'd

- Solution for DSBFC;

i)

$$\boxed{\begin{aligned} P_c &= \frac{(V_c/\sqrt{2})^2}{R} = \frac{V_c^2}{2R} = \frac{(10)^2}{2*10} = 5W \\ P_{usb} &= P_{lsb} = \frac{m^2 P_c}{4} = 1.25W \end{aligned}}$$

ii)

$$P_t = P_c + \frac{m^2}{4} P_c + \frac{m^2}{4} P_c$$

$$= 5 + \frac{1^2}{4}(5) + \frac{1^2}{4}(5) = 7.5W$$

iii) Bandwidth=2xf_{mmax}=2(10kHz)=20kHz

Example 12..cont'd

- Solution : For DSB-SC

ii)

$$P_t = \frac{m^2}{4}P_c + \frac{m^2}{4}P_c$$

$$= \frac{1^2}{4}(5) + \frac{1^2}{4}(5) = 2.5W$$

$$Power_{saved} = 7.5W - 2.5W$$

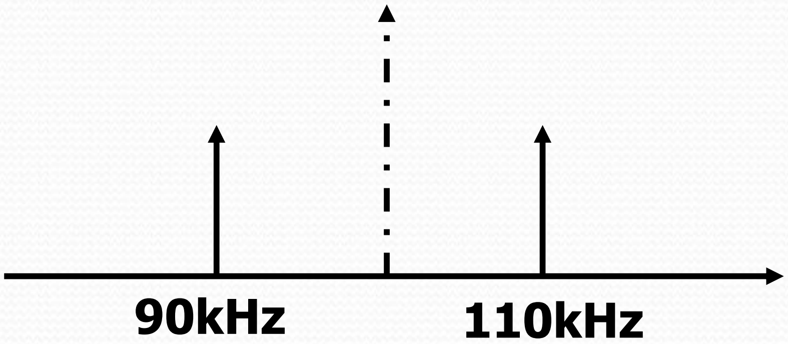
$$= 5W$$

$$\%Power_{saved} = \frac{5W}{7.5W} x100\%$$

$$= 66.67\%$$

iii)Bandwidth=2xf_{mmax}=2(10kz)=20kHz

iv)



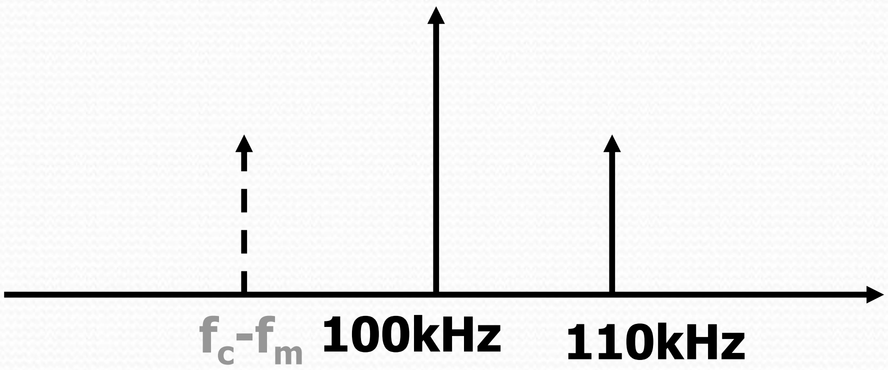
Example 12..cont'd

- Solution: For SSB-FC

ii)
$$P_t = P_c + \frac{m^2}{4}P_c$$
$$= 5 + \frac{1^2}{4}(5) = 6.25W$$

iii)Bandwidth=f_{mmax}=10kHz

iv)



$$Power_{saved} = 7.5W - 6.25W$$
$$= 1.25W$$
$$\%Power_{saved} = \frac{1.25W}{7.5W} x100\%$$
$$= 16.67\%$$

Example 12..cont'd

Solution : For SSB-SC

ii)

$$P_t = \frac{m^2}{4} P_c$$

$$= \frac{1^2}{4}(5) = 1.25W$$

$$Power_{saved} = 7.5W - 1.25W$$

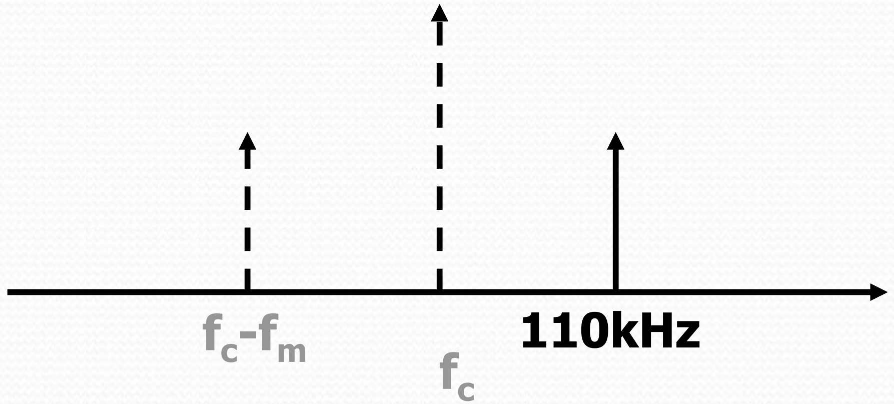
$$= 6.25W$$

$$\%Power_{saved} = \frac{6.25W}{7.5W} x100\%$$

$$= 83.33\%$$

iii) Bandwidth=f_{mmax}=10kHz

iv)



Example 13

- An AM standard broadcast receiver is to be designed having an intermediate frequency (IF) of 455 kHz.
- A) calculate the required frequency that the local oscillator should be at when the receiver is tuned to 540KHz it the local oscillator tracks above the frequency of the receiver signal
- B) Repeat (a) if the local oscillator tracks below the frequency of the receiver signal.

Example 13 Cont.

Solution

- Given f_{IF}= 455 kHz, f_c=540kHz

a) Solving for the upper side

$f_{IF}=f_c - f_{LO}$ → $f_{LO} = f_{IF}+f_c$ = 455 kHz + 540kHz

= 995 kHz

b) Solving for the lower side

$f_{IF}=f_c - f_{LO}$ = 540kHz- 455 kHz= 85 kHz